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Introduction

The basic concept of the LLAMA program was outlined in a previous progress report, PR-1, and in References 1, 2, and 3; a brief summary only will be given here. Basically, a single axis linear accelerometer is being constructed using a proof mass consisting of a small permanent magnet supported by magnetic forces inside a superconducting cylinder. Coaxial coils on either side of the magnet, inside the cylinder, are used to compensate the axial instability of the magnet and also to provide the restoring force to keep the proof mass at null. A sensitive displacement detector is used to feed the restoring coils with control information. Calibration below 10^{-6} g is to be effected by controlled radiation pressure.

Preliminary evaluation of the suspension and of a crude form of the accelerometer has been reported in progress report, PR-2, January, 1965.

From January 1965 until now, the major effort of the LLAMA program has been in the area of displacement detection. A brief breakdown of the work done and the proposed further work are outlined in this report. A more comprehensive treatment is left for the final report to be completed in September 1965. In addition to the final report, a LLAMA Operations Manual will also be prepared.

Displacement Detectors

Two types of displacement detectors are being investigated. One, a more sensitive version of the spot occultation displacement detector (SODD) mentioned in PR-2, is to be used as a coarse detector to confine the floating magnet within a region of several microns. The other, the interferometer displacement detector (IDD) also mentioned in PR-2, is to act as the high sensitivity detector to confine the magnet within a small fraction of a micron.

1. SODD

The spot occultation by one end only of the magnet was used in

early experiments and was adequate for preliminary investigations. The main drawbacks were that the detector did not seek a fixed null since this depended on lamp brightness and an external reference voltage; the output of the detector was d. c.; the detector was sensitive to rotation of the magnet.

For an operational LLAMA system a better coarse detector is needed which is also compatible with the IDD. Figure 1 shows an improved version of SODD which reduces, if not eliminates, the drawbacks mentioned above. By causing the other end of the magnet to occult another spot that originates from the same source, a differential detector results which seeks a fixed null independent of lamp brightness and external reference. By chopping the incident beams alternately, an a. c. output signal is obtained which simplifies the amplification and by suitable filtering can give an improved signal to noise ratio. After phase sensitive demodulation and rectification, an output signal results which corresponds to the magnitude and sense of the displacement. When the magnet is at null, this SODD is insensitive to rotation of the magnet. When not at null, any rotation of the magnet is interpreted as a reduction in sensitivity of the detector.

This SODD configuration was set up using a simulated test mass suspension and the output voltage vs. displacement curve is shown in Figure 2. The linear range of the detector was observed to be around 0.62 mm and the peak signal to noise ratio was 160. This indicated that the uncertainty range of the SODD was ± 2 microns. A helium-neon gas laser was used as the light source. A further increase in sensitivity may be achieved by reducing the spot size still further. Control of the spot size varies the width of the linear range. SODD operation with a floating magnet is about to be carried out.

2. IDD

The IDD configuration described in PR-2 was set up on a 4' x 4' surface plate and used a suitably designed test mass suspension simulator instead of a floating magnet. Because of the high sensitivity of the proposed interferometric set up, high stability fixtures and environment are most essential. At present, some instability in the interference pattern is

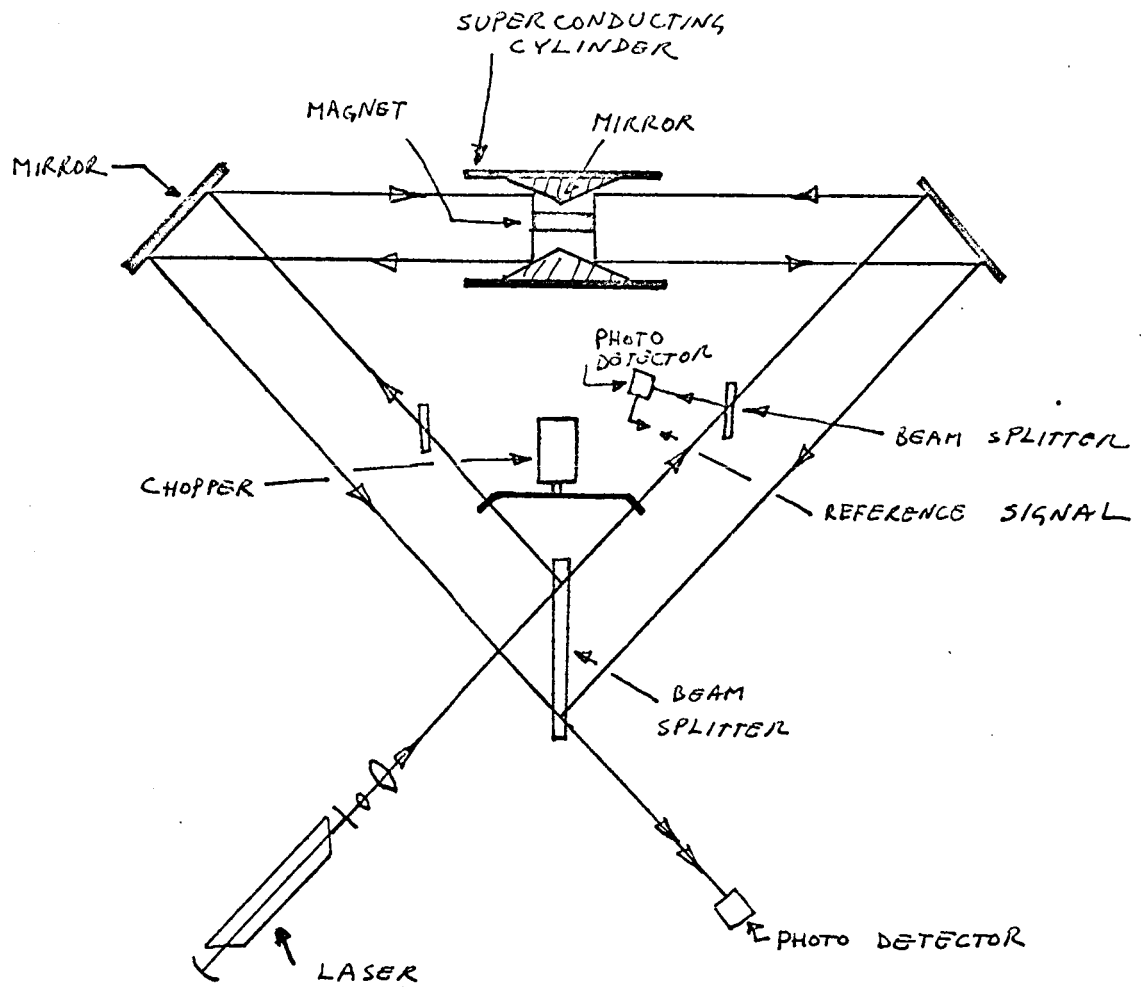


FIGURE 1 . SPOT OCCULTATION DISPLACEMENT DETECTOR (SODD)

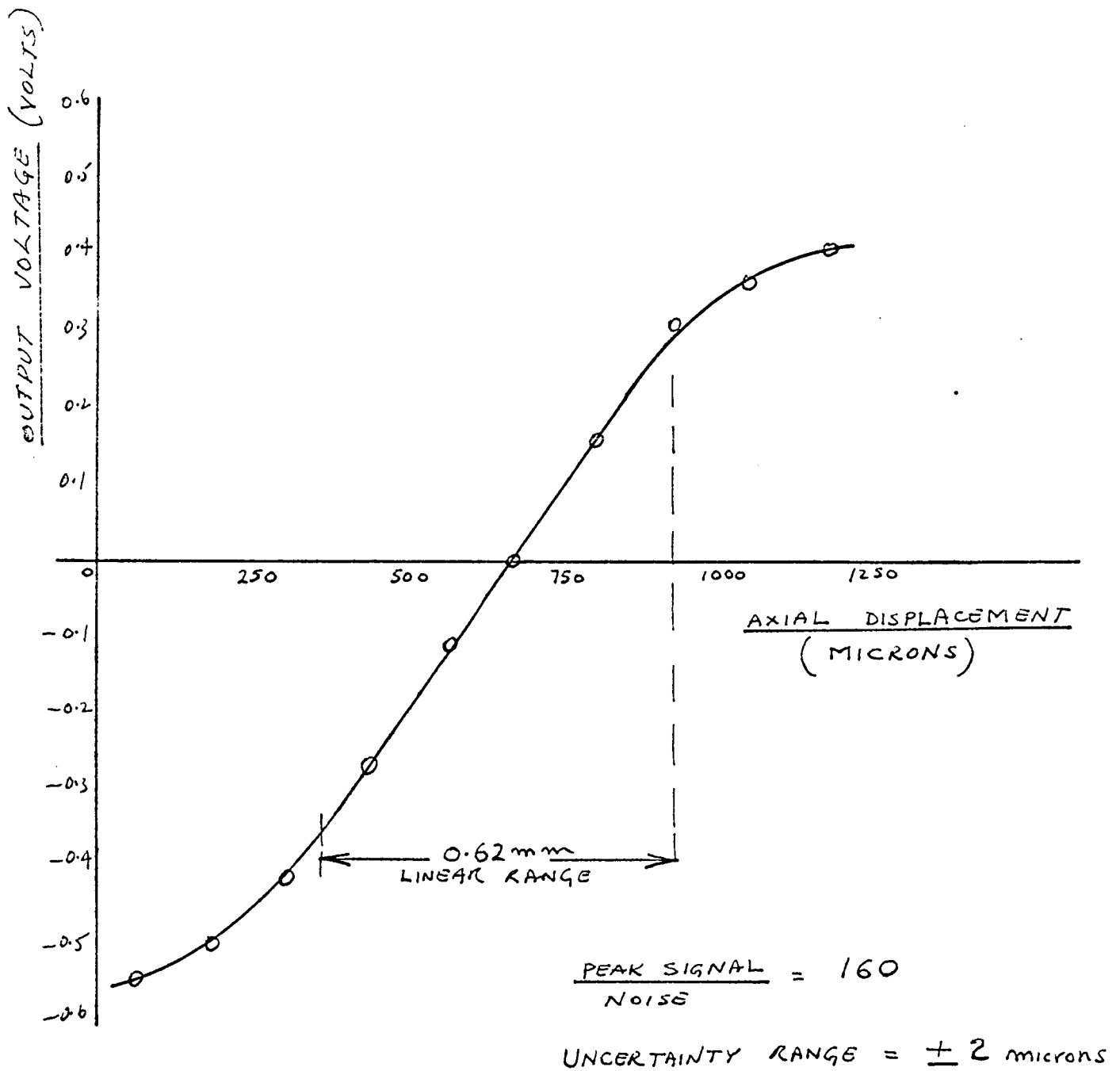


FIGURE 2. S.O.D.D. OUTPUT VOLTAGE Vs. DISPLACEMENT

evident. The cause of this instability is under investigation.

3. Integration of SODD and IDD

It is desirable to design the SODD and the IDD to share as much of the optical hardware as possible, at the same time enabling either detector to operate with, or independently of, the other. Considerable thought is being given to this problem.

At present, it seems feasible to combine the two detectors by the configuration shown in Figure 3. The one laser source illuminates both detectors. The SODD design is chosen to suit the IDD configuration. The size of the optics is dictated by the IDD limit on test mass rotation. The SODD beams are fixed in position and are kept away from the central portion of the beam splitter since the IDD beams move over this area as the test mass rotates. The photo detectors are thus kept adequately apart.

During operation the SODD loop is kept closed so that the test mass is restricted to a region of a few microns throughout. When the test mass is in this uncertainty region the IDD is brought into play by suitable switching logic to reduce the uncertainty region to a small fraction of a micron.

Hardware Construction

Because of the nature of the LLAMA system, precision optical hardware has to be used. Considerable effort has gone into the design and construction of compatible components to be used in conjunction with a large surface plate. Elaborate test mass and suspension simulators have been constructed so that major design problems can be investigated without the need for liquid helium.

Dewar

Several modifications to the LLAMA dewar have been carried out:

- a) Longer antechambers have been installed so as to house longer lucite spoon holders to reach further into the superconducting tube.

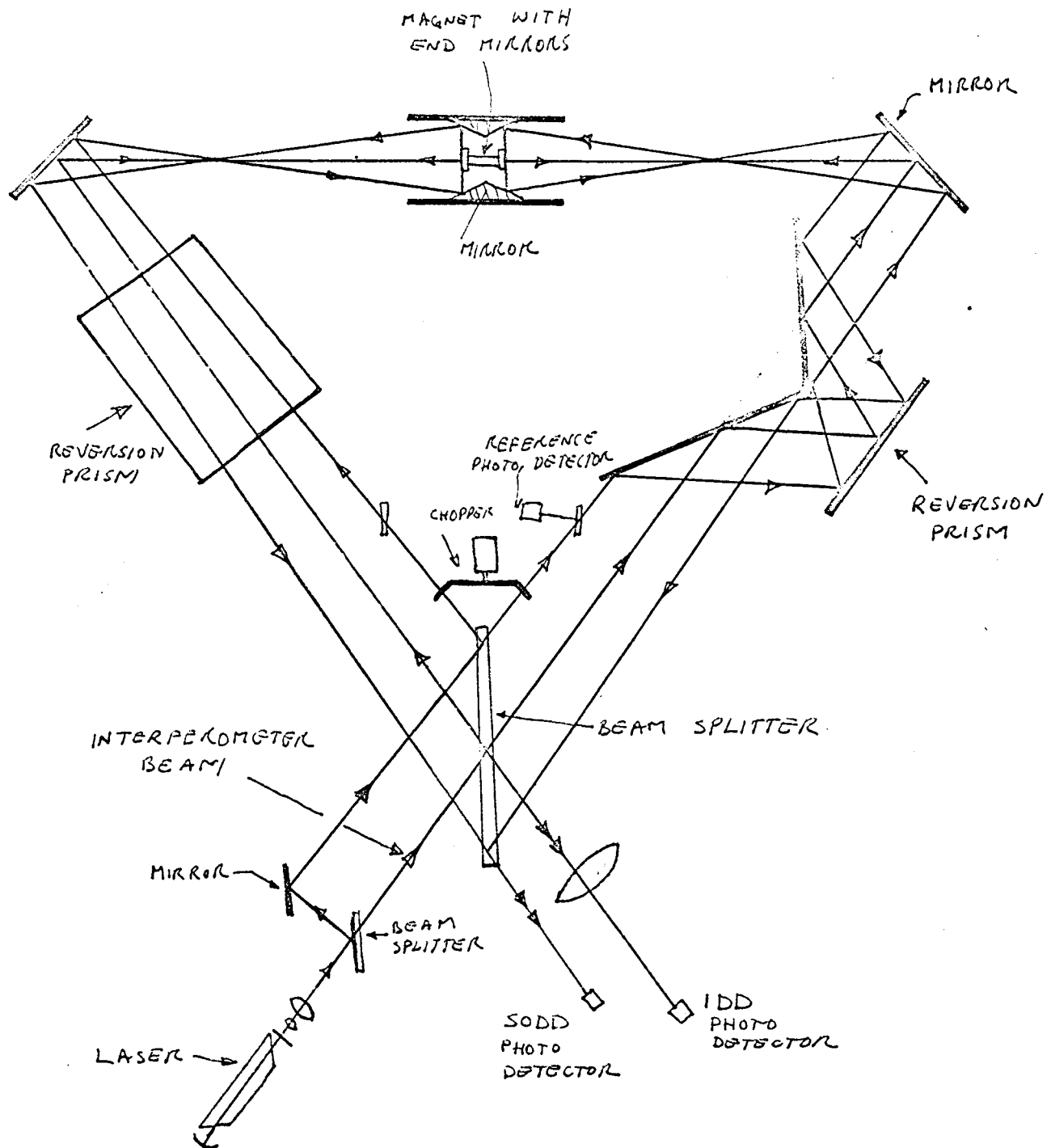


FIGURE 3. CONFIGURATION FOR SODD-IDD COMBINATION

b) An ionization gauge has been fitted so as to measure the pressure in the float environment to determine the effectiveness of the cryopumping action of the liquid helium. If this pressure is found to be greater than 10^{-6} torr then the incorporation of a diffusion pump has to be considered.

Several attempts have been made to float a magnet but these were marred by leaks in the dewar. These leaks were found to be in the inner can which meant that the dewar had to be disassembled for repair. The dewar is now back in operation and several experiments are to be made shortly.

Further Work

The work scheduled for the next few months includes the following:

- a) evaluation of a LLAMA system using SODD.
- b) evaluation of the IDD using a suspension simulator.
- c) modification of dewar for IDD operation.
- d) evaluation of SODD-IDD combination using a floating magnet; determination of control logic, etc.
- e) modification to suspension if required.
- f) evaluation of a complete LLAMA system.

References

1. Chapman, P.K., A Cryogenic Test Mass Suspension for a Sensitive Accelerometer, M.I.T. Experimental Astronomy Laboratory Report, TE-10, June, 1964.
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